Fabrication and Properties of Nanocapacitors and Nanostructures prepared by Nanosphere Lithography

by

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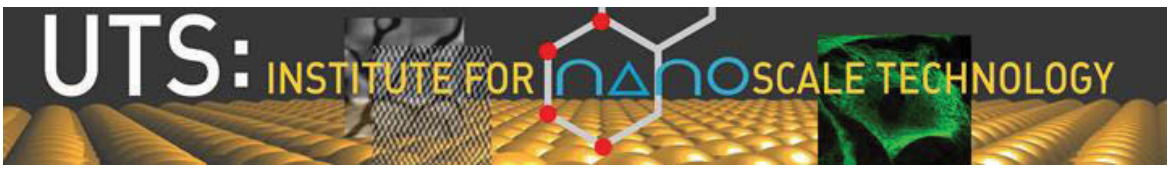

Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as a part of requirements for a degree except as fully acknowledged within the text.

I also certify that the dissertation has been written by me. Any help that I have received in my research work and the preparation of the dissertation has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the dissertation.

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Date:

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Abbreviations

γ- PGA = Poly-γ-Glutamic Acid

AC = Activated Carbon

AES = Auger Electron Spectroscopy

AFM = Atomic Force Microscopy

AMU = Atomic Mass Units

AR NSL = Angle-Resolved NanoSphere Lithography

CAFM = Conducting Atomic Force Microscopy

CL = Cathodoluminescence

DSC = Differential Scanning Calorimetry

CV curve = Cathodic potential or Cyclic Voltammetry curve

CVD = Chemical Vapour Deposition

CVP = Capacitance Voltage Profile

DC = Direct Current

DCM = Dichloromethane

DNA = Deoxyribonucleic Acid

DPV = Differential Pulse Voltammetry

DRAM = Dynamic Random Access Memory

DWCNT = Double-Walled Carbon Nanotubes

EDS = Energy-Dispersive X-ray Spectroscopy

E_F = Fermi level

ESEM = Environmental Scanning Electron Microscopy

fcc = Face-centred cubic

GO = Graphene Oxide

hcp = Hexagonal close-packing

HOMO = Highest Occupied Molecular Orbital

HOPG = Highly Ordered/Orientated Pyrolytic Graphite

HV = High Vacuum

IC = Integrated Circuit

IR = Inner Region

IUPAC = International Union of Pure and Applied Chemistry

IV = Current Voltage

LUMO = Lowest Unoccupied Molecular Orbital

LSV = Linear Sweep Voltammetry

MCC = Metal Carbonyl Cluster

MPC = Monolayer Protected Cluster

MS = Mass Spectrometry

MWCNT = Multi-Walled Carbon NanoTube

n-type = Negative-type

NMR = Nuclear Magnetic Resonance

NSL = NanoSphere Lithography

p-type = Positive-type

PANi = Polyaniline

PEDOT = Poly (3,4-ethylenedioxythiophene)

pFPT = Poly(3-(4-fluorophenyl)thiophene)

pMeT = Poly(3-methylphenylthiophene)

PS = Polystyrene

pTh = Poly(thiophene)

PVD = Physical Vapour Deposition

QCM = Quartz Crystal Microbalance

RF = Radio Frequency

RPM = Revolutions Per Minute

SAM = Self-Assembled Monolayer

SE = Secondary Electron

SDS = Sodium Dodecyl Sulphate

SEM = Scanning Electron Microscopy

SERS = Surface Enhanced Raman Spectroscopy

STM = Scanning Tunnelling Microscopy

STS = Scanning Tunnelling Spectroscopy

Surfactant = Surface active agent

SWCNT = Single-Walled Carbon NanoTube

T_A = Annealing Temperature

TEM = Transmission Electron Microscopy

TFT = Thin Film Transistor

TGA = Thermogravimetric Analysis

TLC = Thin Layer Chromatography

T_M = Melting Temperature

T_S = Substrate Temperature

UHV = Ultra High Vacuum

UTS = University of Technology, Sydney

UV = Ultraviolet

XPS = X-ray Photoelectron Spectroscopy

ZSR = Zero State Response

Publications and Conference Proceedings Arising From This Work

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3. Coutts. M. J.; Zareie. H. M.; Cortie. M. B.; McDonagh. A. M., *Charging of gold/ metal oxide/ gold nanocapacitors in a scanning electron microscope.* Nanotechnology. 2014 **25**(15): p. 155703.
4. Coutts. M. J.; Zareie. H. M.; Cortie. M. B.; Phillips. M. R.; Wuhrer. R.; McDonagh. A. M., *Patterning nanostructures for ZnO nanorod growth. International Conference on Nanoscience and Nanotechnology (ICONN 2010)*. 2010. Sydney, Australia.
5. Riessen. D.; Coutts. M. J.; Zareie. H. M.; McDonagh. A.M., *Ruthenium phthalocyanine thin films on gold*. *International Conference on Nanoscience and Nanotechnology (ICONN 2010)*. 2010. Sydney, Australia.
6. Coutts. M. J.; Zareie. H. M.; Cortie. M. B.; Phillips. M. R.; Wuhrer. R.; McDonagh. A. M., *Solution Growth of Zinc Oxide on Templates Fabricated by Re-emission of Sputtered Materials*. *Inaugural One-day Student Symposium in Inorganic Chemistry*. 2011. School of Chemistry, The University of Sydney, Australia.

Abstract

Nanosphere lithography was used to synthesise nanoscale capacitors as well as arrays of zinc oxide nanostructures. Close-packed polystyrene nanospheres were used as masks and periodic arrays of metals / metal oxides were deposited through the inter-sphere voids onto substrates. The technique was optimised to produce hexagonally close-packed arrays of polystyrene spheres for a range of sphere sizes (200-1500 nm). Nanoscale capacitors were synthesised via evaporative and sputter deposition to produce structures consisting of gold / metal oxide / gold layers on a silicon substrate. A range of metal oxides were investigated including alumina, silica, zinc oxide, titania and hafnia. A significant development reported here involves the charging of these devices and their characterisation using scanning electron microscopy techniques. These methods enable the measurement of the charging time constants of materials in a non-destructive fashion without the requirement to connect wires or contacts. Nanostructures fabricated using zinc oxide as a dielectric material produced rings of zinc oxide nanostructures on the silicon substrate and a mechanism for the ring formation is proposed here. The resultant structures were used as templates to seed the hydrothermal growth of zinc oxide nanostructures. Arrays of zinc oxide nanostructures were also produced using techniques that enable control over the position and amount of growth.